Prodution and Photoactivity spectrum of Ni/TiO_2 core shell nanoparticles

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Abstract

Titanium dioxide (TiO_2) has been widely used in environmental applications of photocatalysis either on photodegradation of pollutants [1] or on photoconversion of solar energy (Grätzel cells [2]). However its direct use is limited by an high energy gap which causes a low light absorption of the solar spectrum. The most common method for solving this problem has been the partial replacement of titanium atoms by doping with other metals (W, Fe, Pt, Ag, ..) or partial substitution of Oxygen atoms with N or P or photosensitising with suitable dyes. Another route is the use of mixtures of particles usually obtained by physical mixing followed by annealing [3a, b]. Utilizing nanoparticles opens new possibilities for the development of novel materials since it allows bottom-up control of its atomic structure. The application of core/shell quantum dots has special relevance in the area of nanotechnology. Previously, photocatalytic activity of core/shell CdSe/TiO_2 in the visible had been established [4]. Recently, the production of magnetic particles with photocatalytic properties in the visible consisting of core/shell magnetite/TiO_2 has been published [5]. This type of particles has the advantage of being easily recoverable from the medium in which photodegradation occurs.
In this work, Ni quantum dots were obtained by laser ablation of a Nickel target with femptosecond pulses from a Ti-Sapphire laser in an aqueous media (figure 1A). Compared to standard ablation in the gas phase, this technique assures a more homogeneous distribution of nanoparticle parameters due to well-defined ablation conditions and rapid cooling in the medium. Subsequently, these nanoparticles were isolated and covered with TiO_2 in methanol using suitable titanium alkoxides through a sol-gel process. After cleaning and drying the resulting particles were dispersed in water.

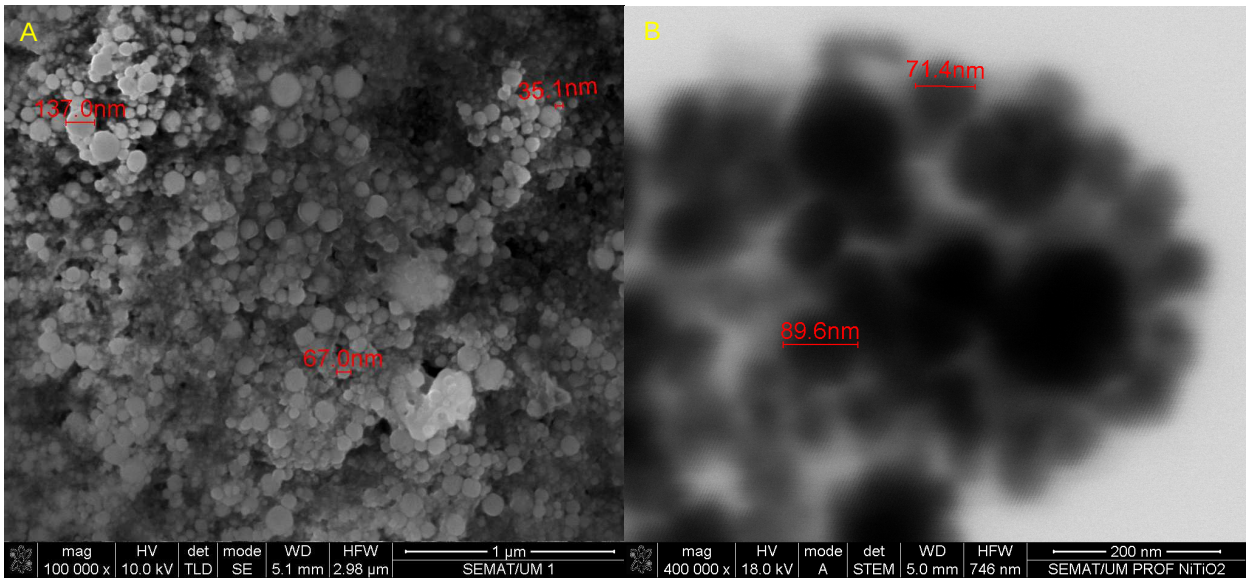

Figure 1: SEM images of Ni nanoparticles (A) and Ni/TiO_2 nanoparticles (B)

Figure 1B shows a SEM image of the produced nanoparticles that were used in photocatalysis experiments that consisted in the photoconversion of coumarin into 7-hydroxycoumarin (figure 2). This process allows for the quantification of the photocatalytic efficiency of hydroxyl radicals production (OH•) by the photocatalyst [6]. The measurement were made as a function of the irradiation wavelength. The resulting photoactivity spectrum was compared with that obtained with standard TiO_2 nanoparticles (P25 from Degussa) (figure 3).

$$Cou + h\nu + Ni/TiO_2 \xrightarrow{k_1} 7HC + Ni/TiO_2$$

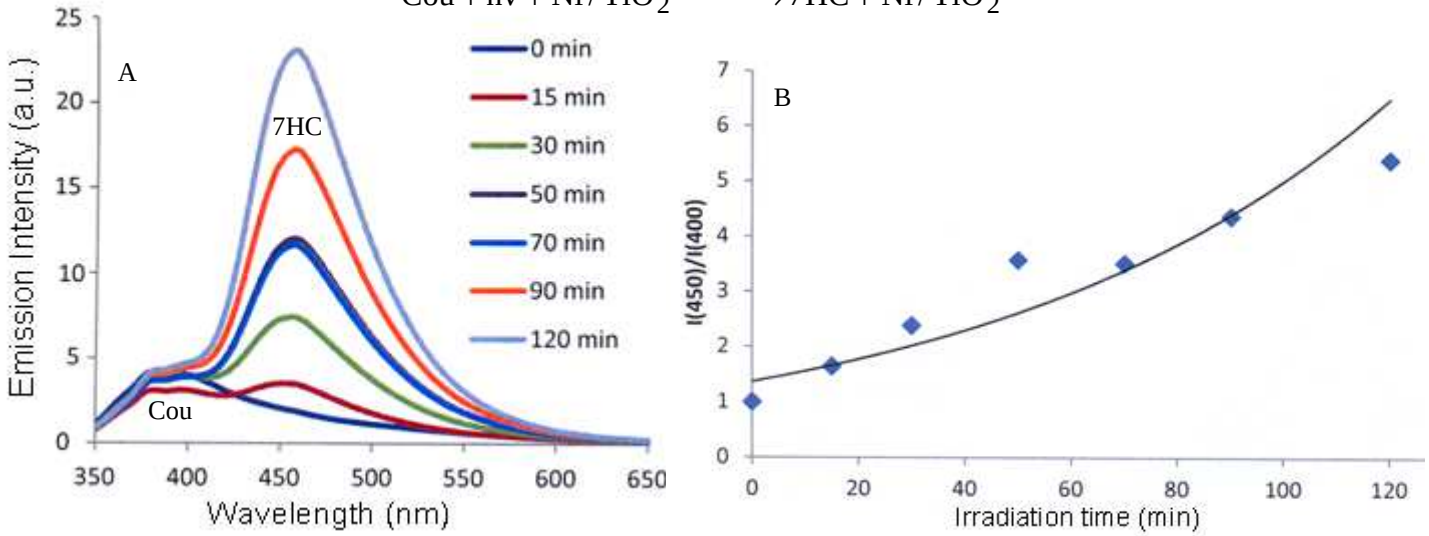

Figure 2: (A) Photoconversion of Coumarin (Cou) into 7-hydroxycoumarin (7HC) using Ni/TiO_2 at 350nm irradiation and Ni/TiO_2 nanoparticles. (B) Determination of pseudo-first order rate constant

$$\frac{I/I_o(450)}{I/I_o(400)} \approx 1 + \frac{[7HC]}{[Cou]} = e^{k_1 t_{irr}}$$

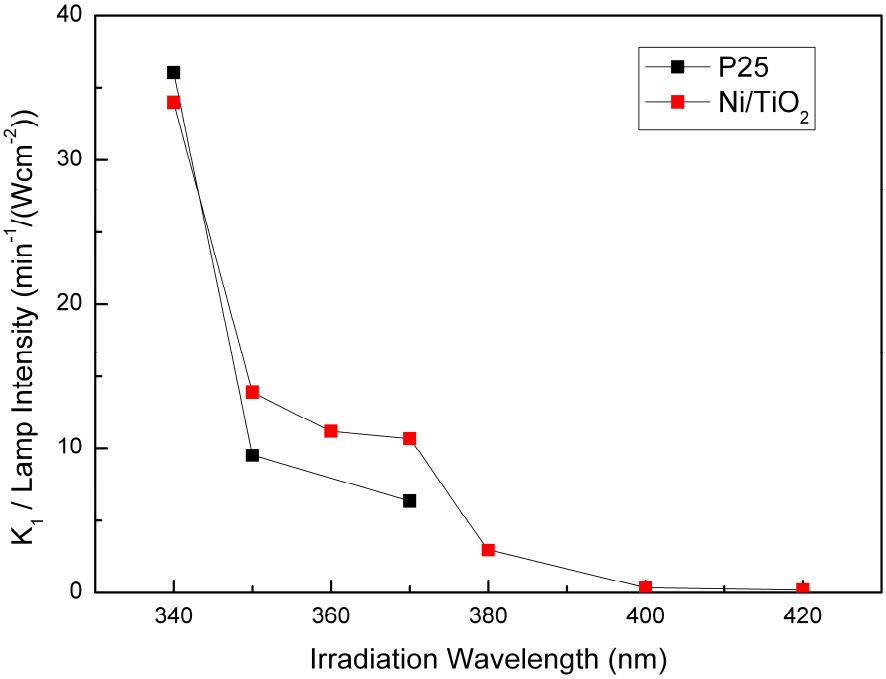

Figure 3: Photoactivity spectrum of Ni/TiO_2 and P25 in the photoconversion of Coumarin to 7-hydroxycoumarin

Acknowledgements: FCT, FEDER, COMPETE/QREN/EU for financial support to CFUM (PEst-C/FIS/UI0607/2011)

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